```python
from pathlib import Path
from typing import List, Tuple, Dict
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import (
    confusion_matrix,
    ConfusionMatrixDisplay,
    roc_curve,
    auc,
    precision_recall_curve,
    PrecisionRecallDisplay,
    RocCurveDisplay,
)
from minisom import MiniSom

# trains a SOM on the input data
def fit_som(data: np.ndarray, grid: Tuple[int, int] = (22, 22), seed: int = 42) -> MiniSom:
    rows, cols = grid  # SOM grid dimensions set to 22x22
    som = MiniSom(
        x=rows, y=cols,
        input_len=data.shape[1],         # number of features
        sigma=3.0,                       # spread of the neighborhood
        learning_rate=0.5,               # speed of learning
        neighborhood_function="gaussian",# type of neighborhood function
        random_seed=seed                 # for reproducibility
    )
    som.random_weights_init(data)
    som.train_batch(data, num_iteration=10_000, verbose=False)  # train the SOM
    return som

# create a lookup table from each SOM node BMU to a majority label
def majority_vote_lookup(som: MiniSom, data: np.ndarray, labels: np.ndarray) -> Dict[Tuple[int, int], int]:
    vote: Dict[Tuple[int, int], List[int]] = {}

    for vec, lbl in zip(data, labels):                 # go through each data point and its label
        bmu = som.winner(vec)                          # find best-matching unit (BMU) for the vector
        vote.setdefault(bmu, []).append(lbl)           # collect all labels that map to this BMU

    # assign each BMU the most common label (rounded average)
    return {bmu: int(round(np.mean(v))) for bmu, v in vote.items()}
```

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# predict labels for new data using the trained SOM and the vote map
def predict_som(som: MiniSom, vote_map: Dict[Tuple[int, int], int],
data: np.ndarray) -> np.ndarray:
    # for each input vector, find its BMU and use the vote_map to
assign a predicted label
    return np.array([vote_map.get(som.winner(v), 0) for v in data])


import time
import psutil
import os

# performs cross-validation using a Self-Organizing Map (SOM)
def som_cross_validate(Syn_df: pd.DataFrame, feature_columns:
List[str], grid: Tuple[int, int] = (22, 22)) -> List[float]:
    accuracies = []
    process = psutil.Process(os.getpid())


    oof_true: List[int] = []
    oof_score: List[float] = []
    oof_pred: List[int] = []

    # resource monitoring starting
    overall_start_time = time.time()
    overall_start_ram = process.memory_info().rss / 1024 / 1024  # in
MB
    overall_start_cpu = psutil.cpu_percent(interval=1)

    # loop over each fold in the dataset
    for fold in sorted(Syn_df["Fold"].unique()):
        train_df = Syn_df[Syn_df["Fold"] != fold]
        validate_df = Syn_df[Syn_df["Fold"] == fold]

        scaler = StandardScaler()
        X_train = scaler.fit_transform(train_df[feature_columns])
        X_validate = scaler.transform(validate_df[feature_columns])
        y_train = train_df["Label"].values
        y_validate = validate_df["Label"].values

        som = fit_som(X_train, grid)
        vote_map = majority_vote_lookup(som, X_train, y_train)
        y_predict = predict_som(som, vote_map, X_validate)

        dist_map = som.distance_map()
        fold_scores = [dist_map[som.winner(x)] for x in X_validate ]
        oof_score.extend(fold_scores)
        oof_true.extend(y_validate.tolist())
        oof_pred.extend(y_predict.tolist())
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        # plot U-Matrix for each fold
        plt.figure(figsize=(10, 8))
        u_matrix = som.distance_map()
        plt.imshow(u_matrix, cmap='bone_r')
        plt.colorbar(label='Distance')
        plt.title(f'SOM U-Matrix - Fold {fold+1}')
        plt.savefig(f"som_umatrix_fold_{fold+1}.png", dpi=300,
bbox_inches="tight")
        plt.show()
        plt.close()

        # accuracy
        acc = (y_predict == y_validate).mean()
        accuracies.append(float(acc))
        print(f"Fold {fold+1}: accuracy = {acc:.4f}")



    cm = confusion_matrix(oof_true, oof_pred)
    ConfusionMatrixDisplay(confusion_matrix=cm).plot(cmap="Blues")
    plt.title("SOM Confusion Matrix")
    plt.show()

    fpr, tpr, _ = roc_curve(oof_true, oof_score)
    roc_auc    = auc(fpr, tpr)
    RocCurveDisplay(fpr=fpr, tpr=tpr, roc_auc=roc_auc).plot()
    plt.title("SOM ROC Curve")
    plt.show()

    prec, rec, _ = precision_recall_curve(oof_true, oof_score)
    PrecisionRecallDisplay(precision=prec, recall=rec,
average_precision=pr_auc).plot()
    plt.title(f"SOM Precision-Recall Curve (AUC = {pr_auc:.3f})")
    plt.show()


    # end of resource monitoring
    overall_end_time = time.time()
    overall_end_ram = process.memory_info().rss / 1024 / 1024  # in MB
    overall_end_cpu = psutil.cpu_percent(interval=1)

    # results
    print("\n══════ SOM Validation Summary ══════")
    for i, a in enumerate(accuracies, 1):
        print(f"Fold {i}: {a:.4f}")
    print(f"Mean Accuracy: {np.mean(accuracies):.4f}")
    print(f"Standard Deviation: {np.std(accuracies):.4f}")

    # resources used
    print("\n Overall Training Stats ")
```

```python
    print(f"Total Training Time: {overall_end_time -
overall_start_time:.2f} seconds")
    print(f"Total RAM Usage Increase: {overall_end_ram -
overall_start_ram:.2f} MB")
    print(f"CPU Usage (at final check): {overall_end_cpu}%")

    return accuracies


# Load the dataset
Syn_df = pd.read_csv("D:\Coding Projects\Detection-of-SYN-Flood-
Attacks-Using-Machine-Learning-and-Deep-Learning-Techniques-with-
Feature-Base\Data\K5_Dataset.csv")

# select first 12 feature columns (exclude label and fold info)
feature_columns = Syn_df.columns.difference(["Label",
"Fold"]).tolist()[:12]

# run cross-validation using a Self-Organizing Map
accs = som_cross_validate(Syn_df, feature_columns)
print("\nFinal SOM Cross-Validation Results:")
print(f"Fold Accuracies: {accs}")

# save the notebook as a web PDF
os.getcwd()
!jupyter nbconvert --to webpdf "d:\\Coding Projects\\Detection-of-SYN-
Flood-Attacks-Using-Machine-Learning-and-Deep-Learning-Techniques-
with-Feature-Base\\Taulant Matarova\\SOM_model_finalv2.ipynb"
```